EMBRACING ENERGY EFFICIENCY:

Ensuring Yukon Benefits from Climate Moderated Heating Demand

energy solutions centre

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Yukon
Energy, Mines and Resources

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Photos

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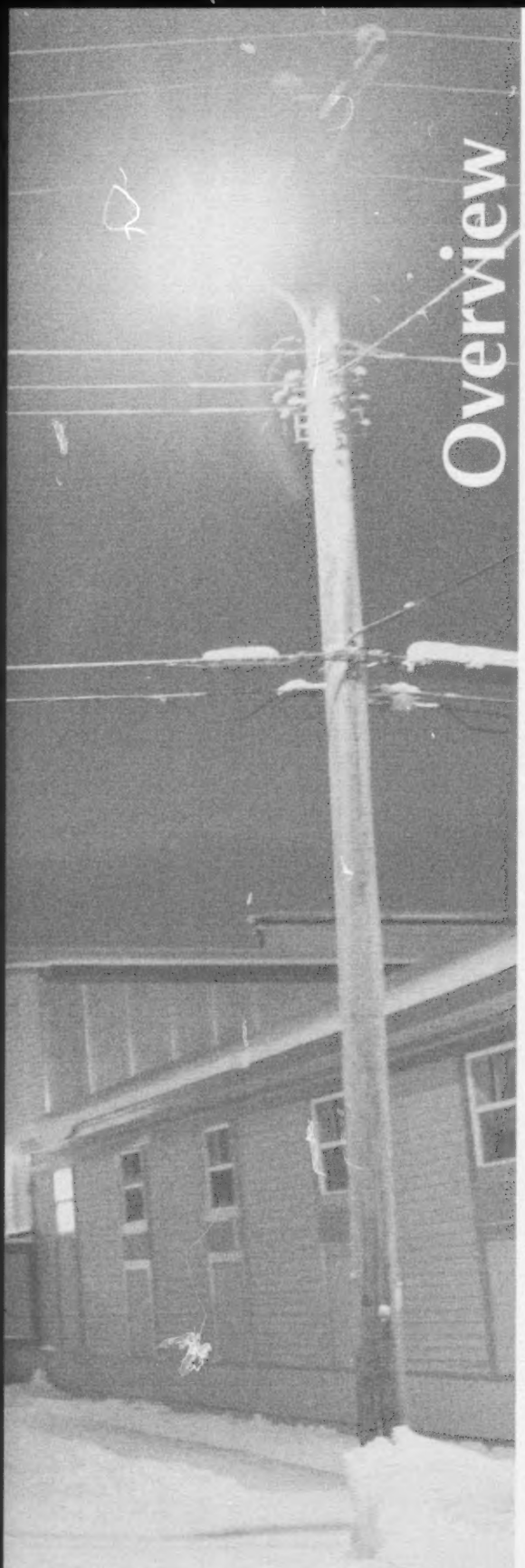


Overview

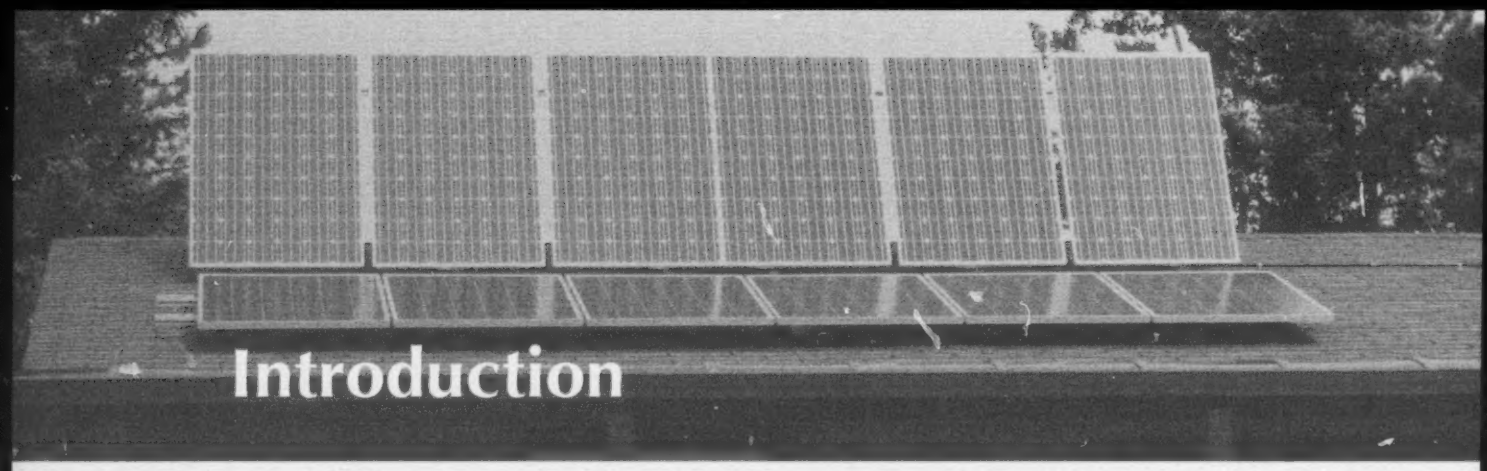
Meeting energy demand, either to provide heat, cooling, or electricity, is essential to healthy and comfortable homes in Canada. However, the cost of meeting this demand, either in the form energy prices, fuel costs or infrastructure maintenance, can be expensive. Climate change can reduce this expense by moderating winter temperatures and reducing the amount of energy required by a household to maintain indoor comfort. Such savings may be especially meaningful for Yukon where seasonal warming will result in a substantial moderation of winter temperatures.

Modelling developed to support this study suggests that the number of heating degree days required in Whitehorse annually will decline significantly over the long-term. This moderating influence may be immediately observable. The number of cooling degree days required annually may increase up to 88 per cent by the end of this century. However, given the amount of energy currently required for cooling is negligible, this would not constitute a significant increase in demand. Even a significant rise in cooling demand will not offset the potential savings resulting from reduced energy demand in winter.

Climate moderated energy demand may reduce daily energy consumption in Yukon by 10 to 137GWh/year over the short term. **Many benefits could result from reduced energy consumption, provided sufficient programming exists to limit the growth of energy consumption as population grows**. A number of actions are suggested that, when combined with an informed and effective approach to energy efficiency overall, will be important to ensure Yukon benefits from a changing climate:

- Investigating the feasibility and utility of time-of-use rates by the Yukon energy sector, including the feasibility of installing a smart-grid in the territory.
- Improved tracking of heating data, including oil sales and volumes, biomass sales, and the sale of electricity for heating purposes.
- Continued testing of cold climate air source heat pumps, energy efficient wood stoves, and commercial wood pellet boilers.
- Continued development of a biomass policy and biomass industry in Yukon.
- Appraisal of market incentives and subsidies to protect low-income households from unanticipated energy costs associated with heating.

The subsequent benefits that could accrue include reductions in electrical infrastructure expenditures, reduced resource pressures, and new economic opportunities. Some secondary benefits resulting from this improved system resilience could be a net reduction in household energy expenses and greenhouse gas emissions. In all climate moderated energy demand, when supported by effective energy efficiency programs and policy, provides a tangible opportunity for a more resilient Yukon beginning in the near-term.



Introduction

Meeting the energy demand of Canadians is essential to maintaining healthy and comfortable homes in Canada. Currently the Canadian energy sector is endeavouring to meet a rising per capita use of energy while simultaneously overhauling aging infrastructure and concentrating on reducing greenhouse gas emissions. The combined expense of such initiatives will likely increase the cost of energy for Canadians. However, some relief may be provided by climate change even if the status quo persists, resulting in reduced energy demand. This relief may result in financial savings and reduced greenhouse gas emissions, thereby make it easier to upgrade Canadian energy infrastructure. The potential savings that may result are especially meaningful for Yukon where seasonal warming will result in a substantial moderation of winter temperatures without increasing summer cooling costs substantially.

There are three, somewhat intuitive, assumptions supporting investigations of these net savings (Mideska et al, 2010):

1. Warming winters will lead to reduced heating demands.
2. Reduced heating demands will lead to energy savings that exceed the increased demand for cooling during the summer months.
3. The overall reduction in energy demand is sufficient to lead to significant economic savings.

These conditions are predicated on the assumption that the risks resulting from a changing climate will not eclipse these savings (Wilbanks et al, 2012). Such risks could include increased threat to infrastructure from forest fire, permafrost, and water shortages resulting from hydrological shifts (Davis and Clemmer, 2014; Zamuda, 2013; Paskal, 2010).

In Yukon, where climate change is expected to exert an appreciable influence on mean annual temperature, these three assumptions will likely hold true. The overall climate trend in Yukon is consistent with, if more pronounced, than the global one. Toward the end of this century winter temperatures are projected to warm by as much as 10°C in parts of northern Yukon while summer temperatures are anticipated to warm by as much as 1-3°C (Bush et al, 2014). As a result the influence of climate change on energy demand in Yukon is predominantly expected to result in a reduced demand for heating in the winter.

When monetized the effects of climate change on global energy demand are compelling. Tol (2002a, 2002b) has estimated that the net savings yielded from reduced heating demand could amount to 0.3per cent of the global gross domestic product by 2100. In other words, climate change may reduce electricity and fossil fuel consumption in winter that may result in financial savings for Yukon residents.

However, when one considers the growing Yukon population, the severe northern winter climate, and increasing use of electricity for heat, some doubt exists as to the long-term influence of climate change on energy demand. In this case, as energy demand grows while the climate changes, increased consumption would exacerbate the vulnerability of Yukon's electrical infrastructure. The resulting pressure on energy resources and require a more rapid overhaul of the grid (Zamuda, 2013). Obviously such a scenario would yield few benefits to the Yukon public and effectively constitutes a reversal of the anticipated course for the country as a whole.

The Government of Yukon and the Yukon Energy Corporation have therefore partnered with the objective of testing the three noted assumptions to see if they are valid in Yukon and determine what, if any, risks and opportunities may result from climate moderated energy demand. The investigation begins with a review of academic literature on this subject to determine how energy markets may be affected by warming temperatures. The report then examines the specific effects of climate moderated demand on Yukon's energy market and concludes with some discussion of any risks or opportunities that may subsequently emerge.

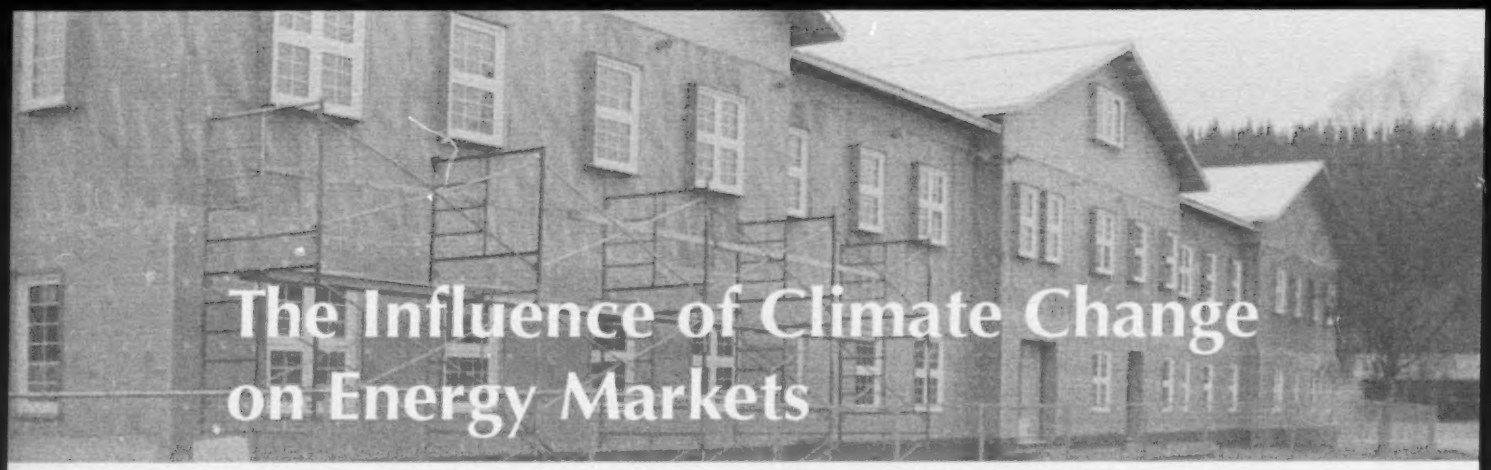
Terminology

Throughout this report **"near term"** is used to reference the 2011-2040 climate normal, while **"medium term"** refers to the 2041-2070 climate normal, and **"long term"** refers to the 2071-2100 climate normal.

"Energy" refers to the heat and electricity required to maintain indoor comfort at a threshold of 16°C. A base temperature of 16°C has been utilized for the purposes of this report in keeping with the best practices used by the Yukon Energy Corporation.

"Heating degree days" (HDD) are a standard method for modelling the effects of climate change on energy demand (Mideska et al, 2010; Isaac, 2009) and refer to the "sum of negative deviations of the actual temperature from the base temperature over a given period of time" (Mideska et al, 2010: 3580).

"Cooling degree days" (CDD), conversely, are predicated on the number of positive deviations from the base temperature. The most logical choice for a base temperature is the temperature at which energy use is minimal, although it should be noted that base temperature varies with region, income and lifestyle, and will vary with time (Isaac and von Vuuren, 2009).



The Influence of Climate Change on Energy Markets

Climate change will have a number of direct and indirect effects on global and local energy markets. Direct effects result from shifts in the timing of local demand patterns caused by changing temperature and precipitation regimes and their effect on indoor comfort (Mansura et al, 2007). Countries with milder climates, for example, will likely see a decisive shift in their consumption patterns as demand for cooling rises above demand for heating. Such countries will include most of Europe, India and China (Aebischer et al, 2007; Taseka et al, 2012). However, for countries at more northerly latitudes such as Canada and Russia, this should not be the case. In these countries energy demand will be moderated by a more appreciable increase in winter temperatures which, when combined with a slight increase in summer temperatures, results in a net decline in demand because more than half of energy is used for heating. The resulting decrease in heating demand may yield financial savings for households and industry (Isaac and von Vuuren, 2009). In general an increase of 1°C is expected to reduce energy consumption by 5 per cent with a potential national savings in the billions of dollars (Mideske and Kallbekken, 2010; Franco and Sanstad, 2008).

Intuitively, because HDD and CDD are dependent on temperature, rising mean annual temperatures should decrease HDD and increase CDD (Mideska et al, 2010). This intuitive evaluation is supported by the modelled effects of climate change on global energy demand developed by Isaac et al (2009). This model suggests that Canada will experience significant decrease in HDD accompanied by a significant increase in CDD by 2100. The projected HDD and CDD, along with projected and measured baseline values, are provided in **Table 1**.

Precipitation can also affect indoor comfort by influencing humidity although it has far less impact on indoor comfort than temperature. For example, lower temperatures are usually considered more comfortable if the humidity is also low. Fewer HDD are required as a result (Mansura et al 2007).

Table 1: *Projected Effects of Climate Change on HDD and CDD Values in Canada*

	HDD	CDD
From measured values	4493	171
Modeled average 1971-1991	4766	81
Modeled 2100	3663	321

(Isaac and von Vuuren, 2009)

Both the benefits and risks emerging from shifting energy demand will be influenced by regional variation in climate impacts imposed by latitude and altitude (Isaac and von Vuuren, 2009). For example, as the annual climate of the US warms, the shift in energy demand in San Francisco will be very different from the shift observed in Chicago (Isaac and von Vuuren, 2009). Local climate regimes are also susceptible to weather fluctuations, which create "elasticities" (i.e. the possible range of energy demand necessary to keep indoor temperatures constant and comfortable) for both heating and cooling that result in significant inter-annual variability in peak load requirements. The effects of weather on demand are more significant for heating demand and can yield very different seasonal peak load requirements (Mideska and Kallbekken, 2010). Regional elasticities in winter may have a significant influence on the extent of any economic or emissions reduction benefits that may result from climate change given HDD may have a greater impact on energy consumption and carbon emissions than CDD (Mideska and Kallbekken, 2010). Other climatic variables that may affect energy demand include wind speed, evaporation, evapotranspiration, and cloud cover (Parkpoom et al, 2004). It should be noted that the direct influence of climate change on energy demand will vary significantly between regions due to the number of local variables affecting load requirements.

The Impact of Climate Change on Global Energy Markets

The primary concern, evident in a scan of the available literature on this subject, is the impacts of increased cooling (for example, Mideska and Kallbekken, 2010; Aebischer et al, 2007). While this is not likely to be as significant a concern for Canada, it is worth noting because it is so central to the global discussion, and may seriously affect other countries/continents. For example, the rise in CDD for Africa by 2100 is projected to be 1672 per year, while HDD is expected to decrease by 223, resulting in a net increase of 3355 CDD - or 153 per cent of their current annual expenditure of energy on heating and cooling (Isaac and von Vuuren, 2009). Carbon emissions resulting from energy generation will subsequently increase and exacerbate the onset and severity of climate change through a positive feedback cycle. Household vulnerabilities will increase as annual energy costs rise and divert resources away from any necessary adaptations at the local level (Isaac and von Vuuren, 2009). In short, unless significant action is taken to meet the energy needs of countries at more equatorial latitudes through energy efficiency and renewable energy sources, the combination of climate change and energy demand will undermine global efforts to manage both.

The negative influence of increased cooling demand globally emphasizes Canada's opportunity. Canadian energy consumption may decrease approximately 18 per cent by 2100 as the global climate warms (Isaac and von Vuuren, 2009). This net decrease may result in the following opportunities:

- Reduced infrastructure expenditures in response to peak shaving (Wilbanks et al, 2012).
- Reduced resource pressures in winter accompanied by less perceptible, albeit increasing, resource pressures in summer (Wilbanks et al, 2012).
- Improved system resilience in winter as loads decrease (Franco and Sanstad, 2008).
- Increased local economic growth driven by greater consumption by households corresponding to a net reduction in energy expenses (Gonseth and Vielle, 2012).
- Reduced emissions from fossil fuels required to meet heating loads (Isaac and von Vuuren, 2009).

Several long-term risks and market transformations may also affect the energy sector despite an overall reduction in HDD (Mideske and Kallbekken, 2010):

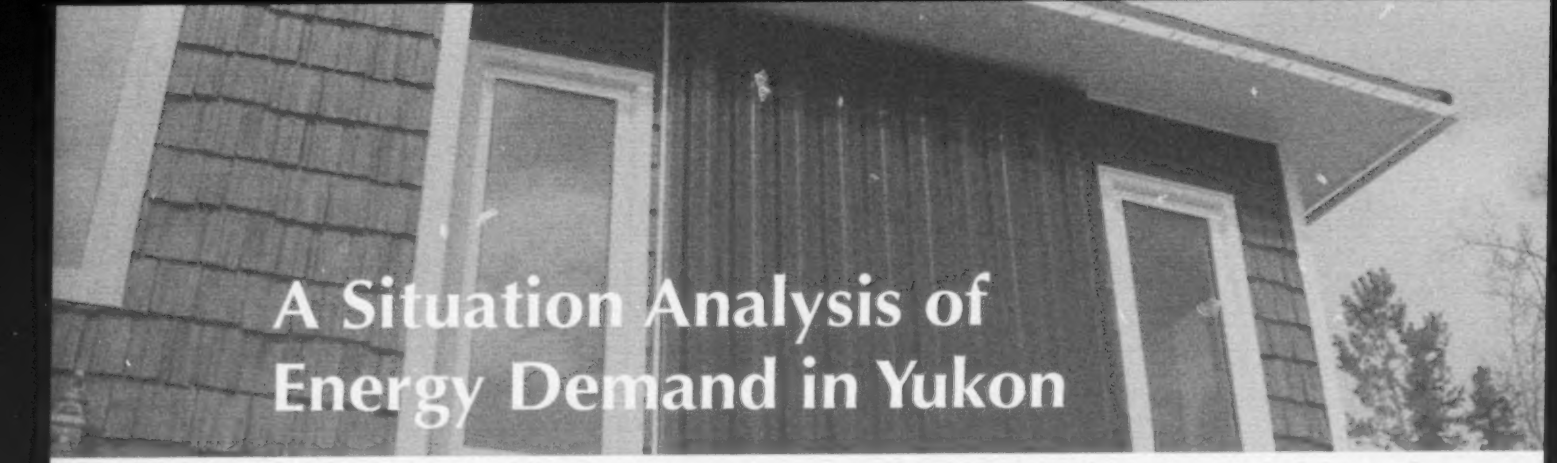
- The incidence of extreme weather events could affect the transformation and transportation of electricity resulting in a rising vulnerability of transmission infrastructure.
- Significant regional changes in the provision of heat, such as increases in fuel costs if resources are stressed by climate change, which escalate the cost of energy.

Non-climate related variables will also exert direct and indirect pressures on energy markets. These non-linear variables can have a significant impact on energy demand (Mansura et al, 2007). For example, population growth exerts a significant direct influence by increasing residential demand and can place an appreciable pressure on existing resources regardless of their availability (Isaac and von Vuuren, 2009; Wilbanks et al, 2012). Aging populations also directly influence energy demand. Wilbanks et al (2012) report that aging cohorts can consume up to 2.5 times the energy per capita for heating than other age groups. More indirect influences can include (Franco et al, 2008):

- Resource availability, including the need to develop new generation, which will influence fuel costs and preferences.
- Aging transmission infrastructure and replacement costs.
- An increase in the per capita consumption of energy regardless of moderated winter temperatures[1].
- Public pressures, such as demand for renewable resource power generation in an effort to curb greenhouse gas emissions.
- New technologies.

These direct and indirect factors influencing energy demand are highly dynamic and regional. An understanding of regional characteristics and pressures is therefore integral to anticipating the risks and opportunities that may emerge as climate change influences energy demand in Yukon.

[1] *Jevon's Paradox* suggests that as technology improves the resulting efficiency improvements increases, rather than decreases, the intensity with which energy resources are used.



A Situation Analysis of Energy Demand in Yukon

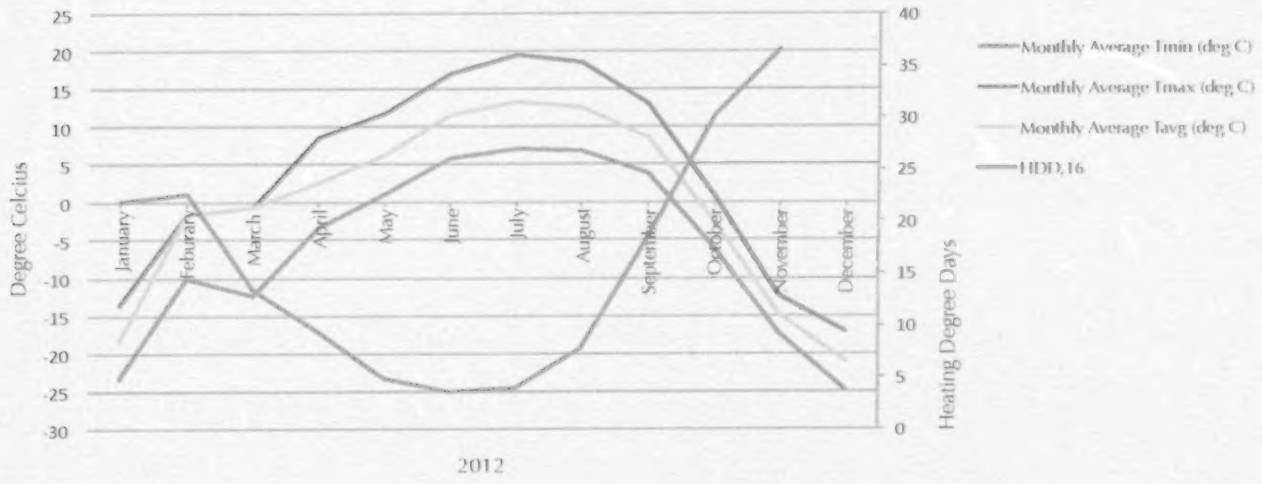
Energy demand in Yukon is largely driven by light and temperature. Over the summer months demand drops due to long daylight hours and warmer temperatures. Demand increases in the winter when temperatures drop well below 0°C and daylight can last a matter of hours. Seasonal temperatures are therefore inversely related to energy demand. The correlation between energy and temperature is demonstrated in **Figure 1**.

Yukon energy demand is likely to grow over the near term. The peak demand for electricity, illustrating load growth, is estimated to increase 2.26 per cent per annum, as a product of population growth and the new housing construction required to meet it (Yukon Energy Corporation, 2013).

Meeting Yukon's Electricity Needs

Hydro-generation accounts for approximately 93.7 per cent of Yukon's electricity generation annually (Yukon Electrical Company Limited, 2013). Fossil fuel generation, primarily through the combustion of diesel, is utilized to meet demand when it exceeds hydro supply during the winter months. For example, on 16 January 2015, a record instantaneous load of 83.69 MW was recorded by Yukon Energy Corporation. Of the power produced to meet instantaneous demand 12.4 MW, or 14.8 per cent of power, had to be met through diesel generation at a cost of $4,340/MWh produced (Yukon Energy Corporation, 2015).

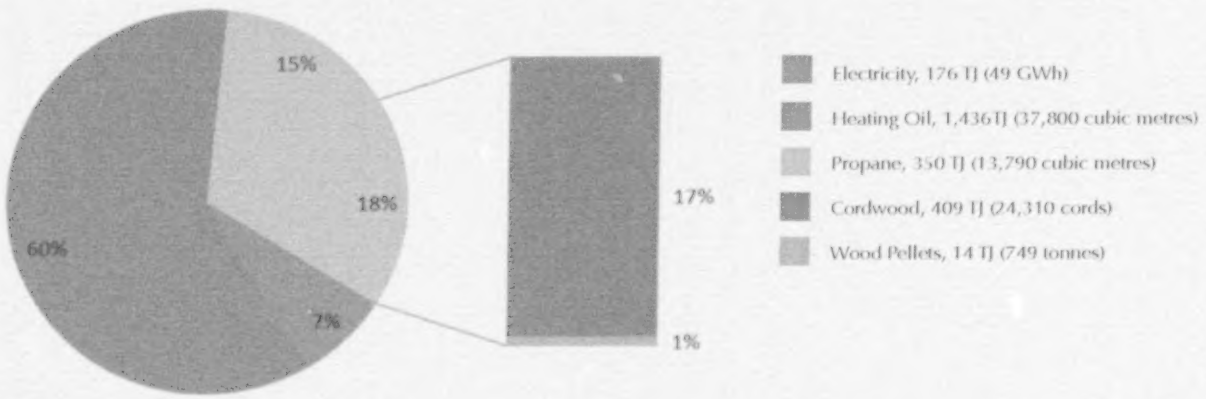
Figure 1: *Monthly annual temperature when compared to HDD, Whitehorse, 2012*

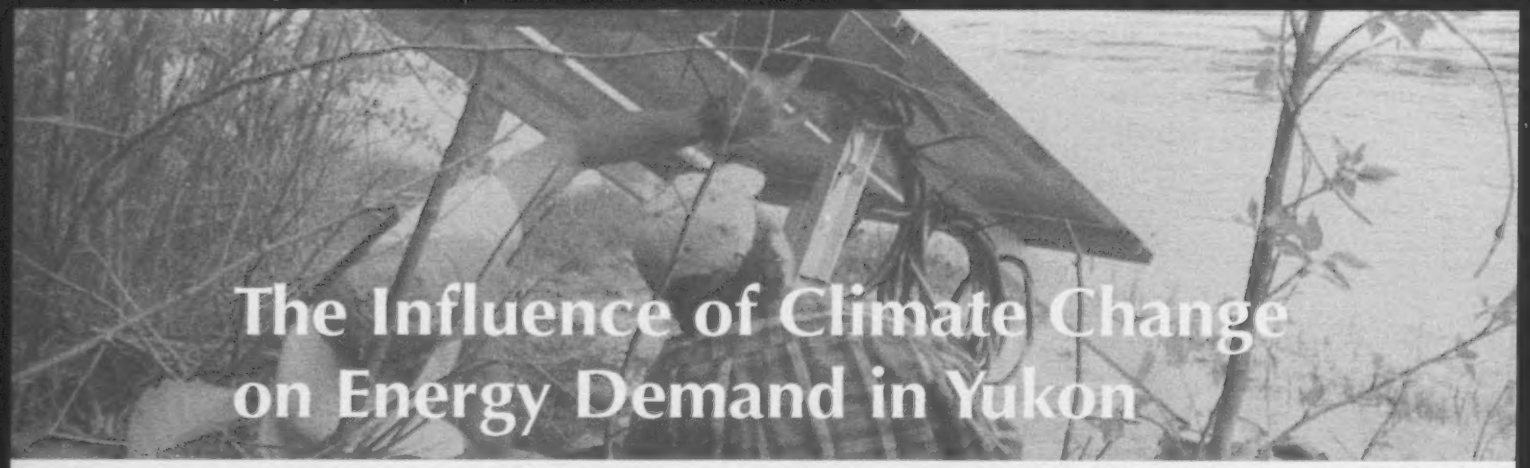


Meeting Yukon's Heating Demand

Heating demand in Yukon is met through a broader range of fuel types that are distributed by local suppliers. These fuels include cord wood and wood pellets (collectively referred to as biomass), heating oil, and propane. A growing proportion of Yukon's commercial and residential sectors are now using electric heat. **Figure 2** provides a consolidated break-down of heating consumption by fuel based on ICF Marbek's inventory (2011a and 2011b). At this time domestic hot water and electric heating consumed 19 per cent of total residential electricity use. Heating, air conditioning and ventilation accounted for 22 per cent of commercial sector energy use. By 2030 space heating is anticipated to rise to 24 per cent of residential electricity use at the same time that domestic hot water declines by 13 per cent. Commercial sector consumption for space heating is anticipated to rise 179 per cent over the same period (Yukon Electrical Company Limited and Yukon Energy Corporation, 2013).

Figure 2: *Breakdown of Yukon Heating Market by Fuel Type and Output (TJ)*





The Influence of Climate Change on Energy Demand in Yukon

Climate change will exert an overall warming trend on Yukon over the long-term. Climate change projections for Yukon were prepared by OURANOS in the spring of 2013. The projections are based on the RCP 26, RCP 45, and RCP 85 base scenarios supported by the Intergovernmental Panel on Climate Change (IPCC) for the near-term (2011-2040), medium-term (2041-2070) and long-term (2071-2100). The projected changes in temperature when compared against the base period (1971-2000) for each model are provided in **Table 2**. The projected baseline compares well with the measured average temperature over the same period recorded at Environment Canada's Whitehorse weather station. *The climate of Whitehorse is used as a proxy for Yukon climate throughout the remainder of this report.*

The projections suggest an annual increase in mean annual temperatures of 2.0°C to 5.5°C by 2100, and correlate well with other published projections of climate warming, which suggest a warming of 1.8°C to 5.4°C[2] over the same period (Bush et al, 2014).

The warming of Yukon's climate varies, and will continue to vary, seasonally (Bush et al, 2014). Over the long-term Yukon summer temperatures may rise by between 1°C and 3°C, while winter temperatures may warm by 5°C to 9°C, depending on latitude and altitude (Bush et al, 2014). Yukon winters will warm to a greater extent than summer as a result.

Table 2: *Projections of Yukon Climate Change for Average Annual Temperature (°C)*

			2011 - 2040		
Model	1950 - 1970	1971 - 2000	RCF 26	RCF 45	RCF 85
ENVIRONMENT CANADA	-1.47	-0.71	-	-	-
CANSEMS2		-1.09	1.19	1.21	1.40
CCSM4		-1.12	0.20	0.80	0.58
CNRM-CM5		-0.81	0.65	0.52	0.88
CSIRO-MK3-6-0		-0.97	0.08	-0.07	0.12
GSDL-ESM2G		-0.85	0.34	-0.24	0.34
HADGEM2-ES		-1.06	0.81	0.90	1.04
MIROC5		-1.09	0.28	0.35	0.43
MPI-ESM-LR		-0.91	0.73	0.46	0.97
MRI-CGCM3		-0.83	0.00	-0.13	0.25

[2] Based on the B1 and A2 SRES scenarios of the IPCC.

Changes to seasonal atmospheric temperatures will influence the extent of heating and cooling demand in Yukon. The projections suggest a moderating influence on Yukon temperatures, with warming temperatures occurring in the winter and summer. These findings are consistent with the model of Isaac et al (2009), which also projected a net increase in heating and CDD, as summer and winter temperatures rise.

It should also be noted that Yukon energy demand will be influenced by extreme weather events although a determination of likelihood and severity of such events is outside the scope of this report. It is more or less a certainty that an increased incidence of warm spells, including heat waves, will rise over the long-term. It is also likely that the incidence of deep cold snaps will decrease with seasonal warming, although it is hard to determine the significance of warming winter temperatures in Yukon, where even a 9°C rise in winter temperatures would still allow for prolonged periods of -30°C. Extreme temperature events in summer and winter may therefore be of concern to energy planners in Yukon going forward.

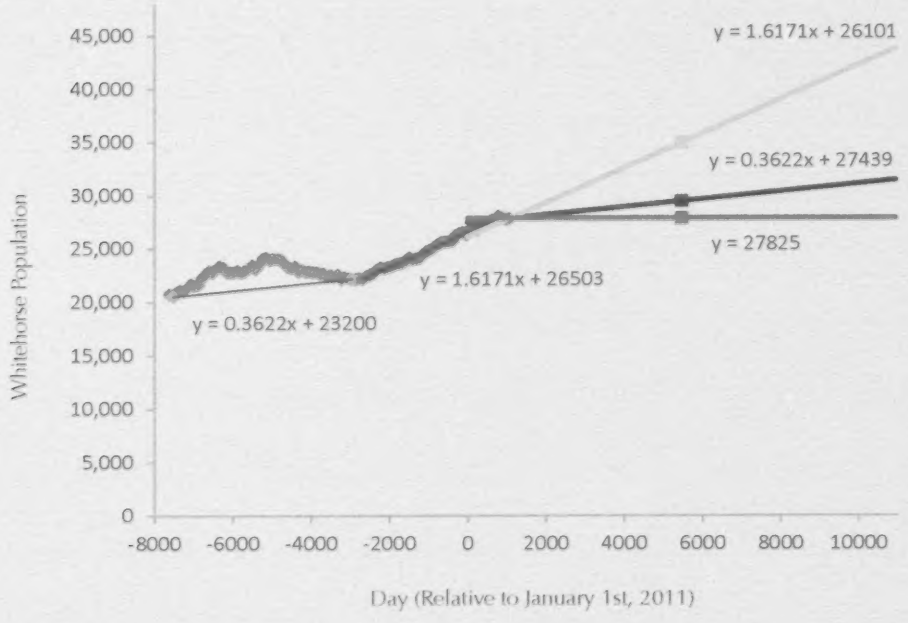
2041 - 2070			2071 - 2100		
RCP 26	RCP 45	RCP 85	RCP 26	RCP 45	RCP 85
-	-	-	-	-	-
2.04	2.78	3.74	1.81	2.73	6.17
1.18	1.80	2.35	0.93	2.27	4.77
1.10	1.51	1.92	1.15	2.36	4.36
0.63	1.78	2.13	1.38	2.25	4.37
0.16	1.29	1.39	-0.21	1.10	3.02
1.65	2.37	3.62	1.57	3.47	6.38
0.75	1.17	2.51	1.28	1.88	4.13
0.98	1.76	2.79	1.01	3.06	5.12
0.29	0.73	1.20	0.38	1.20	2.54

Yukon Population Growth Trends

Population growth will have a significant impact on future energy demand in the territory. Residential population growth has accounted for the bulk of new energy demand since 1990 and has steadily depleted the surplus hydro capacity recorded when the Faro Mine shut down in 1998 (YEC, 2013). Residential load growth tied to future population therefore increases constitutes a significant pressure on generation capacity in the near and medium-terms (YEC, 2012).

A model was constructed from historical data from March 1990 to December 2013 (YBS, 2014) to provide some insight into how load growth may be affected by population pressures. Three population growth trends were developed to assess the implications of zero, medium and high potential growth rate from 2013 to 2030. These near term trends are presented in **Figure 3**. Population was not projected past 2030 given the challenges of accurately demonstrating growth over long periods.

Figure 3: *Population Trends from 1990-2013 and 2040 Projections in Whitehorse*



These trends demonstrate the considerable variability of Whitehorse population growth over the baseline period and, given the substantial differences between the trends, emphasize the challenges of planning for future growth in the territory. Average projected population levels for the near term are 27,825, 29,422, and 34,955 respectively.

Modelled Impacts on Climate Change on Heating and Cooling Degree Days

The population estimates and the projected increase in average annual temperature described in the preceding section together form the basis of the energy demand model developed by Yukon government Energy Branch to quantitatively assess the impacts of climate change on HDD and CDD. A detailed description of the model, its assumptions, and any noted deficiencies, are provided in **Appendix A**: Detailed Discussion of Energy Demand Modelling to 2100.

The results of this model are not surprising. Rising seasonal and annual temperatures will very likely decrease the number of HDD and increase the number of CDD required necessary to maintain an indoor temperature of 16°C. Put simply, as temperatures warm, more energy will be required to keep things cool and less will be required to warm things up. These findings are broadly consistent with those reported in the literature and for Canada.

HDD will be reduced significantly over the long-term and a moderating influence will be exerted by warming winter temperatures almost immediately. It should be noted that the overall decrease in HDD over this century identified in the modeling results, demonstrating a medium reduction in HDD of 1044 HDD or 17per cent, is comparable with the projected long term decrease of 830HDD or 18per cent projected for Canada in Table 1. **Table 3** provides a range of projected HDD over the near, medium, and long-terms.

The quantity of CDD required to cool during warmer Yukon summers is negligible over the near term and will increase with time. A specific projection of CDD was not developed for this report because Yukon Energy Corporation does not currently track CDD. However, given the correlation between the HDD projections for Yukon and those generated by Isaac et al (2009), an 88 per cent increase in CDD may occur over this century. Even an 88 per cent increase in CDD over the long-term is not likely to result in demand load growth large enough to be of concern.

Anticipated Impacts of Climate Change on Energy Demand

The modelled impacts of climate moderated energy demand suggest that the key assumptions identified by Mideska et al (2010) will hold true for Yukon and the net effect of climate change on energy demand suggests there will be a daily reduction in consumption of about 44MWh over the long-term based on the measured daily consumption in 2012 This reduction equates to 16GWh/year or approximately 1 per cent of Yukon's current total generating capacity. A decrease in energy demand per person will result starting in the short-term and become progressively more evident over time. The effect of climate change on Yukon energy demand, based on a zero growth estimate of population, is accounted for in **Table 4**.

It should be noted that the addition of an industrial customer, such as a mine, will eclipse any potential electrical savings resulting from a reduced heating load. For example, the connection of two industrial customers (Victoria Gold and Carmacks Copper) would add a load of 1,58GWh/year to the existing of energy demand (YEC, 2012), which dwarfs the 16GWh/year demand that may be mitigated by climate change independent of population growth.

Table 4: *Annual MWh Conserved through Climate Moderated Energy Demand*

	WHITEHORSE:				YUKON:		
Year	HDD/day	MWh/day	Reduction, MWh/day	Reduction, MWh/year	MWh/day	Reduction, MWh/day	Reduction, MWh/year
2012	17.32	714.43	-	-	1171.87	-	-
2030	15.32	686.42	28.02	10226.28	1143.85	28.02	10226.28
2050	14.98	681.69	32.74	11949.77	1139.13	32.74	11949.77
2080	14.12	669.60	44.83	16363.60	1127.04	44.83	16363.60

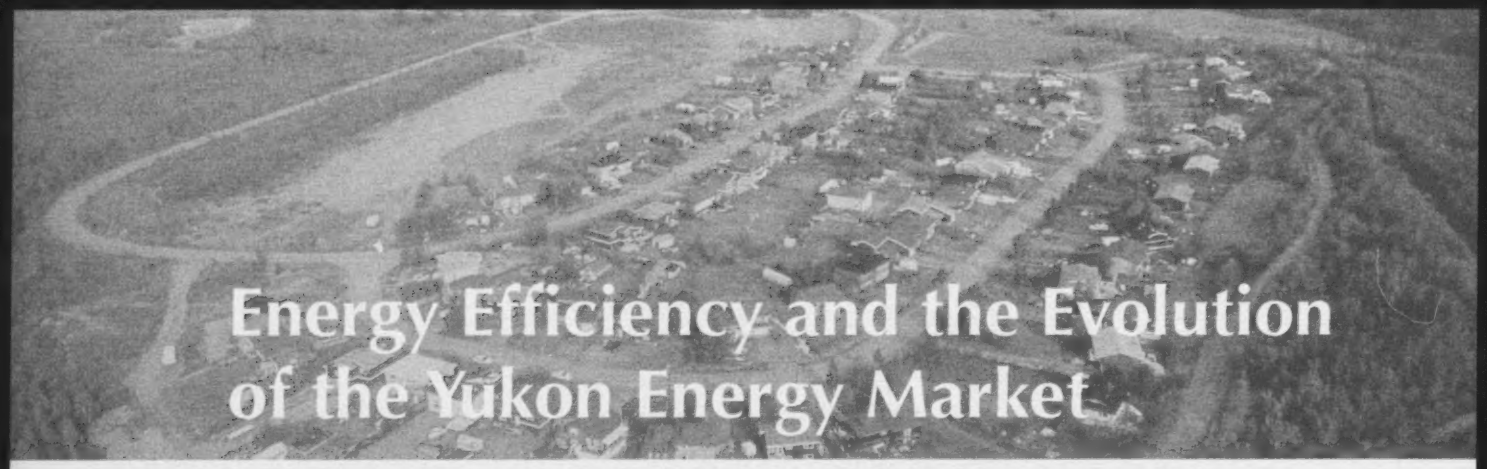
The slight reduction in energy demand projected by the model may become more significant if population increases. As suggested by **Table 5** and **Table 6** respectively rising population will lead directly to increased energy consumption as more houses require energy to maintain indoor comfort. More people will subsequently need to consume more energy even if per capita energy consumption decreases as a result. Jevon's paradox could compound this dynamic and per capita energy consumption may increase even if less energy is required to heat a home. As a result, unless energy use is managed, any reductions in energy resulting from a changing climate could easily be rendered moot. However, if population grows and per capita energy consumption does not increase with it, then potential climate moderated energy savings could amount to 137GWh/year by 2040. The energy saved is equivalent to approximately 30 per cent of Yukon Energy's current generating capacity. **A combination of climate moderated energy demand and responsible energy use may therefore provide a significant opportunity to manage electricity in the territory**. The relationship between energy efficiency and the risks and opportunities of a climate moderated energy market are explored in the following section.

Table 5: *Average Daily Energy Demand as Calculated from Heating Degree Day Models*

	Average Daily MWh (HDD Models)								
	2030 Normal			2050 Normal			2080 Normal		
Population trend	10th	50th	90th	10th	50th	90th	10th	50th	90th
Contrast	694	683	676	692	679	648	677	666	639
Low Increase	785	774	768	-	-	-	-	-	-
High Increase	1103	1092	1085	-	-	-	-	-	-

Table 6: *Average Daily Energy Demand as Calculated from Temperature Models*

	Average Daily MWh (Temp. Models)								
	2030 Normal			2050 Normal			2080 Normal		
Population trend	10th	50th	90th	10th	50th	90th	10th	50th	90th
Contrast	692	686	673	690	677	645	675	664	636
Low Increase	784	778	765	-	-	-	-	-	-
High Increase	1102	1096	1082	-	-	-	-	-	-



Energy Efficiency and the Evolution of the Yukon Energy Market

Energy efficiency must be a priority if Yukon is to derive a net benefit from climate moderated energy demand because:

- Warmer winters should lead to reduced energy demands as outdoor temperatures rise.
- This reduction in energy demand could amount to 16GWh/year. The energy savings resulting from climate change could rise to 137 GWh/year by 2040 if the increased consumption resulting from population growth is effectively managed.
- Without the effective management of energy consumption population growth, combined with Jevon's paradox, will likely eclipse these potential savings.
- Some risks and opportunities do therefore exist with regard to climate moderated energy demand.
- The effective management of energy consumption is critical to accruing a net benefit from climate change impacts on energy demand.

The remainder of this section explores how any climate change related risks and opportunities for the energy sector can be managed through energy efficiency activities targeted at reducing energy consumption and ensuring a net benefit for Yukon emerges over time. While such a discussion is feasible, it should be noted that it is subject to a number of constraints, and does not constitute a prediction of the future territorial energy market. Rather the discussion is intended to suggest how Yukon energy planners can incorporate climate moderated energy demand into their work to ensure a net benefit results.

Potential Risks and Benefits for Electricity Generation

Declining resource availability during a time of rising energy demand is arguably the greatest risk that can be anticipated within a context of changing demand for the electricity generating sector. Currently, Yukon relies primarily on its hydro resources for electricity generation, using fossil fuels used to supplement or backstop hydro supply. Four isolated communities rely entirely on diesel power generation. While glacier melt due to rising temperatures or increased evapotranspiration rates may both affect hydro flows, and hydro generating capacity (Gonseth et al, 2012), recent studies suggest that neither is a concern for Yukon. For example, the Northern Climate Exchange (2014) reports that glacial flows will increase hydro potential over the medium term. The Scenarios Network for Alaska Planning (2011) has also reported a minimal shift in evapotranspiration with some regional drying occurring over the long-term. These studies suggest that there may be an opportunity, at least in the near or medium terms, to benefit from increased hydro flows and hydro generating capacity if winter energy demand is reduced by climate change.

A potential, but important, combination may therefore emerge in the short to medium-term, characterized by reduced demand pressures and a slight increase in generating capacity. This combination would functionally decrease the need to build new generating infrastructure and subsequently freeing capital needed to manage electricity consumption. Managing consumption in this case will be important to

meeting a rising electrical heating load and rising residential and commercial demand that will otherwise increase the "peaks" and deepen the "valleys"of electricity demand.

Practical methods for offsetting these peaks and valleys include using time-of-use rates[3] established for peak shaving and demand-side management programs intended to reduce energy consumption. Either method will require significant time and investment to be successful, including development of supporting programs and policies, and the installation of infrastructure such as a smart grid. Implementing these measures will take time and sufficient capital investment to be successful and the risk of policy costs and poor implementation will rise if insufficient lead time is not provided. As a result energy planners in Yukon must remain cognisant of climate change and keep pace with opportunities as they emerge.

If successful, however, the resulting moderated rates would reduce the cost of consumption to Yukon households and establish the foundation for improved economic spending that would accompany the decreasing energy costs for families. Other benefits that may accrue include reduced resource pressures, reduced consumption of fossil fuels, reduced pressure on thermal generating infrastructure, reduced emissions, and improved winter resilience.

Potential Risks and Benefits for the Heating Sector

The obvious impact of climate change on the heating sector is a reduction in demand for fuel over time. Unlike the electricity sector, which is centralized and utility-led, the heating sector is decentralized and made up of small distributors. Changes in heating fuel consumption will therefore directly impact the heating sector and the economy of Yukon.

Hydro and biomass will exert an increasingly important influence on Yukon's heating sector, since they represent the most viable renewable resource options for heating. Selection of renewable fuel types would also impact the existing residential heating sector heating oil providers by reducing their market share. However, a preference for these options by the Yukon public has already been reported (Yukon Energy Corporation, 2011), and an increased use of renewable resources for heating does have the potential to improve system resilience because such resources are under local control and are potentially sustainable. This resilience is further enhanced if future climate conditions support productivity over the long-term. For example, assuming climate conditions support improved forest productivity, then a greater reliance on biomass would result in a higher degree of resilience over a heating system predicated on the import of fossil fuels.

[3] Time of use rates offer an incentive to flatten peaks and fill in valleys by establishing more expensive rates during period of high demand (peaks) and cheaper rates during periods of low demand (valleys). For example, the Ontario Ministry of Energy currently offers a peak energy rate of $0.14/kWh and an off –peak rate of $0.07/kWh. Time-of-use rates typically require a smart grid to implement (Government of Ontario: http://www.energy.gov.on.ca/en/smart-meters-and-tou-prices/).

The dynamics of such a discussion are complex and difficult to forecast over the long term, given the ambiguities inherent to projections of forest productivity (Williamson et al, 2009). If productivity does increase a long-term preference for renewable heat based on biomass harvesting would result in economic diversification in Yukon communities via the emergence of a forest industry that would distribute wealth throughout the territory. The benefits of local economic development would potentially make up for any disruption that may occur due to the a reduction in the consumption in heating fuel.

Heating fuel choices may also be influenced by outdoor climate and there is some evidence to suggest that climate change may shift how people select heating fuels. For example, electric heat is often selected in areas with warmer winters, while oil is often preferred in areas with colder winters, and natural gas can be favoured in areas of higher precipitation (Mansura et al 2007). Unfortunately it is well beyond the scope of this study to suggest the implications of climate on heating fuel preferences, but if the Yukon is already favouring renewable heating sources, then a shift in winter climate conditions (however slight) may act to further influence the heating market and swing demand away from oil. Several factors may therefore come into play that will influence the heating sector, in particular fossil fuel providers, which will have to be managed to ensure a net benefit accrues to the Yukon economy.

Such a net benefit is possible if reduced heating demand and increased demand for local and renewable resources evolve along the pattern described above. These benefits include reduced greenhouse gas emissions, improved system resilience, reduced resource pressures, and economic development in Yukon communities. Increased use of renewables such as biomass would also carry the benefit of reducing infrastructure pressure by decreasing electricity consumption for heat. However significant changes in policy and program offerings will be required to ensure such a pattern emerges. A risk consequently exists that a rapid transformation may occur in the heating market that the public sector will not be prepared for. For example, as has already been suggested, a rapid move toward electric heat without sufficient mechanisms to manage the added pressure on the grid may mean problems will outstrip benefits as available hydro is not sufficient to meet demand and diesel is used to meet demand at a high economic cost. Adequate policy by energy planners is therefore necessary to meet future market shifts and protect the interests of Yukon's heating sector and the public. The tracking of fuel consumption in the territory is, and will continue to be, integral to developing successful policy to manage this transformation. Fuel sales, such heating oil sales are currently tracked, however, problems exist with regard to accessing and managing the data that inhibit monitoring change in the sector. Improved tracking of all fuel sales is imperative to monitor change.

Emerging technologies will exert a significant influence on Yukon's heating sector regardless of climate moderated outdoor temperatures. Emerging technologies include a range of electric heating options and efficient wood stoves. At this time, the speed with which such heating technologies and associated energy efficient residential products (e.g. insulation) will become viable is not known as their viability will depend on economies of scale, performance in a cold climate, and many other variables that can challenge investment. However, it should be noted that the performance of these emerging technologies may improve once warmer outdoor temperatures exert a consistent influence, improving their viability in Yukon. For example, a reduction in HDD will improve the performance of some new products such as air-source heat pumps, which lose operating efficiency at lower temperatures. In turn, the emergence of new technologies will influence the heating sector, especially if supported by policy and planning. It is therefore important to continue to track the performance of these technologies over the near and medium terms.

One final element of change that may influence Yukon's heating sector is the greater demand for heat reportedly required by aging populations. As noted, aging cohorts can consume up to 2.5 times the energy per capita for heating than other age groups (Wilbanks et al, 2012). While an aging of the population can be moderated by new immigration, this is not expected to be the case in Yukon where new immigration is anticipated to fall well below the national average by 2025, and population growth in Whitehorse is expected to stabilize over the short to medium terms (Conference Board of Canada, 2013). An aging population is consequently expected to become the norm (Conference Board of Canada, 2013). If older cohorts of Whitehorse do require additional heating needs, on a presumably lower household budget than that available to younger cohorts, then a risk may emerge that retirees are required to forgo comfort in favour of budget. A vulnerable minority may subsequently emerge. A continuing appraisal of market incentives and low-income energy subsidies is therefore required.

The future of Yukon's heating sector is dynamic and too many uncertainties exist to suggest a firm path that will mitigate the risks and ensure the opportunities outlined above. However, several near-term actions are still evident and include adequate market tracking, the continued roll-out of effective incentive programs to ensure the heat remains accessible to low-income members of the community, monitoring trends in emerging heating technologies, and supporting biomass to stimulate local economic development. The effective implementation of such measures should ensure a resilient economy and ensure Yukon is adequately prepared for pending changes that will affect the heating sector.

Energy Efficiency and Fostering a Resilient Future

The modelling completed for this study confirms that heating needs of Yukon will decline over the long-term because of warming atmospheric temperatures. This moderation may reduce daily demand by 10 to 137GWh/year over the short-term and is subject to both future per capita energy consumption and population growth. Any opportunity associated with climate moderated warming is predicated on the effective management of energy consumption and of changes in the heating sector. Insufficient management of these two variables will reduce, if not eliminate, potential benefits due to increased infrastructure vulnerability and resource pressures.

A number of actions are suggested to manage the potential market transformation to ensure Yukon residents profit from potential opportunities as they emerge. These short term actions, suitable for implementation over the coming decade, include:

- Investigating the feasibility and utility of time-of-use rates by the Yukon energy sector including the feasibility of installing a smart-grid in the territory.
- Improved tracking of heating data, including oil sales and volumes, biomass sales, and the sale of electricity for heating purposes.
- Continued testing of emerging technologies such as cold climate air source heat pumps and energy efficient wood stoves and commercial wood pellet boilers.
- Continued development of a biomass policy and biomass industry in Yukon.
- Appraisal of market incentives and subsidies to protect low-income households from unanticipated energy costs associated with heating.

These actions, combined with an informed and effective approach to energy efficiency over the long-term, will be important to ensure Yukon's vulnerability to a changing climate is not increased via the energy sector. The resulting benefits that may accrue will include reductions in electrical infrastructure expenditures, reduced resource pressures, and new economic opportunities. Some secondary benefits resulting from this improved system resilience could be a net reduction in household energy expenses and greenhouse gas emissions. In all climate moderated energy demand, when supported by effective energy efficiency programs and policy, provides a tangible opportunity for a more resilient Yukon beginning in the near-term.

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Appendix A:

Detailed Discussion of Energy Demand Modelling to 2100